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Diesel Emissions Reduction

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3. Gamble JF, and Battigelli MC. Epidemiology. In: Clayton GD and Clayton FE. eds. Patty's industrial hygiene and toxicology. New York: McGraw Hill, 1978: Vol 1; 113-116.

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Diesel Emissions Reduction*

Summary

The 'Collaborative Diesel Research Advisory Panel' (CDRAP) was established to resolve a number of issues including: a criterion to evaluate the comprehensive toxicity of the major components of diesel exhaust, research and development to produce add-on exhaust hardware, the study of other techniques to reduce emissions from diesel engines, measurement of the impact of such devices on the underground environment and the strategy to improve mine environments, reduce ventilation costs, increase productivity and improve safety underground, depending on the circumstances of each case. These matters are elaborated in general in this paper.

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Introduction

Diesel-powered machines were gradually introduced into underground mines in Europe in the 1940s to improve some aspects of coal mining operations. Their introduction into North American mines began in earnest in the 1950s. By the early 1960s many North American non-coal mines were employing diesel machinery, but its use in coal mines remained limited.

The general perception has been that untethered diesel machines provide flexibility, which, in turn, fosters improved operating efficiency and increased productivity. This perception persists to date, but not without voices that question this viewpoint when the entire mining system is considered. There is also a current view that a combination of fixed and flexible machines may prove to be a better system for some mining operations.

To cope with the increasing use of diesel machines, regulatory agencies in the major mining nations undertook R&D for the development of standards for the use of such machines underground. Notable among these efforts was the work of John C. Holtz, *et al.* at the United States Bureau of Mines (USBM) in Pittsburgh. This work was well-defined by 1960,[1] providing supporting data for the ventilation provisions of the several USBM-fostered standards for diesel application in several types of mines.[2]

The energy crisis of the mid-1970s caused the Western nations to review the use of the entire spectrum of petroleum-based products. The high thermal efficiency of diesel engines suggested an increase in their use relative to others in all applications, in turn raising the fear that a many-fold increase in urban air-borne particulate matter could result, potentially producing a severe health impact.

These circumstances stimulated renewed interest on the part of government regulatory authorities in North America and were the catalyst for the R&D collaboration of three mining-oriented agencies: the United States

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Bureau of Mines, the Ministry of Labour (MOL) of the Province of Ontario and the Canada Centre for Mineral and Energy Technology (CANMET).

Initiation of the Three-Government Collaboration

In an effort to protect the health of mine workers in Canada's heavily dieselized mining industry (27 per cent of the free world's estimated 15,000 machines), a comprehensive plan for diesel-related health and safety R&D was formulated during 1977.[3] This timing coincided with the availability of Canadian government funding as a direct result of the energy crisis. The plan confirmed two initiatives taken the year before and placed them into a continuing program that suggested the need for inter-government collaboration. These two initiatives were: (a) the formulation of a comprehensive criterion for evaluating the combined impact of the several toxic constituents of diesel exhaust leading to the Air Quality Index expression described below, and (b) the determination of the performance of the then-current water scrubbers and catalytic purifiers.

Because two-thirds (i.e. 2,700 machines) of the Canadian underground diesel machine fleet were in the jurisdiction of the Province of Ontario, there was considerable concern on the part of that provincial government, which was sensitive to the mounting criticism of the use of diesels by the miners themselves.

Consequently, because of these concerns, because the mining sector makes a substantial contribution to Canada's overall economy and because much of the mining industry was dieselized, the perception grew in Canada that the time was right to launch a major study.

The U.S. Bureau of Mines' original initiatives in this field are described above. In addition to those strong beginnings, efforts on the part of the bureau resulted in the achievement of a significant milestone in January 1973. This milestone, the Pittsburgh Symposium[4] on the use of diesel-powered equipment in underground mining, along with a number of other important matters relating to this evolving study, are described by Schnakenberg.[5] That reference describes the co-operation of the U.S. Bureau of Mines and its sister agencies: the Mining Enforcement and Safety Administration, now called the Mining Safety and Health Administration (MSHA), the National Institute of Safety and Health (NIOSH), and also the American Conference of Governmental Industrial Hygienists (ACGIH), for the period from 1973 to 1978. That co-operation fostered the evolution of the view

that further research into diesel exhaust control and health impact studies were necessary.

At the ACGIH November 1978 Industrial Hygiene Symposium, the CANMET Air Quality Index approach, formulated by I.W. French and A. Mildon,[6] and discussed in the next section, was first presented. The initial results of the bureau's environment monitoring efforts performed by Michigan Technological University were described and the MSHA/NIOSH silica/diesel exhaust study was presented.

All these important developments preceded an informal discussion between representatives from Canada and the United States at the 1979 International Conference of Safety in Mines Research Institutes, which proposed a joint research program for the development of hardware to substantially reduce diesel emissions, as well as the continued development of environmental assessment techniques. Similar discussions at the 1980 American Mining Congress reinforced the need for a joint R&D program. These discussions were followed by a meeting in 1980 of three funding agencies in Pittsburgh: USBM, MOL and CANMET, along with a major contractor, the Ontario Research Foundation (ORF). The purpose of the meeting was to report the status of diesel emissions R&D and to lay plans for formal collaboration. Such a co-operative program was instituted by the signing of a Memorandum of Understanding during December 1981, and the Collaborative Diesel Research Advisory Panel (CDRAP) was formed.

Among the first matters undertaken was the installation of an advanced engine test facility at the Ontario Research Foundation, with major support from the Ontario Ministry of Labour. This facility featured: (1) computer-controlled dynamometers to simulate vehicle duty cycles, (2) a dilution tunnel sampling system to cope with dynamic sampling of particulate matter, (3) sophisticated analytical equipment necessary for monitoring the several gaseous, liquid and solid constituents in diesel exhaust, and (4) development of Ames mutagenic assessment capacity to flag potential occurrence of carcinogens.

The panel has subsequently been the vehicle for the sharing of R&D results not only among the funding agencies but also among the several contractors and contributing private sector manufacturers, equipment users and regulatory agencies. The panel has also been the vehicle for consultation on the directions that future R&D should take to achieve the four main objectives listed in the abstract. The minutes of the panel meetings have been

widely distributed throughout the mining community to inform all concerned of the activities and progress.

The highlights of the achievement of these objectives are described briefly in the remainder of this paper.

Selection of the Measure of Progress

Diesel emissions contain a number of constituents that are toxic to those exposed to high enough concentrations for long enough periods of time. Discovering the safe levels and periods of exposure is a process, and perceptions as to appropriate values of these parameters change as experience and understanding grow.

Of the many constituents in diesel exhaust, six are the cause of varying degrees of concern: carbon monoxide (CO), nitrogen dioxide (NO_2), nitric oxide (NO), sulphur dioxide (SO_2), aldehydes and soot. Table 1 indicates their general order of present concern from least to greatest and the reduction in the general magnitudes of these tail-pipe levels over time (for the higher range of levels for full load/speed conditions). These reductions are due to the developments in two-stage combustion or indirect injection of fuel (IDI) relative to direct injection (DI) over the last 20 years. Finally, the Table gives the dilution ratios necessary to reduce these tail-pipe levels to the ACGIH TLVs or other appropriate levels.

Table 1 **Undiluted Contaminant Levels in Diesel Exhaust at Full Load/Speed Engine Operation**

Constituent	Units	Prior Generation Engine Levels (DI)	Present Generation Engine Levels (IDI)	TLV or Other Limit	Present Dilution Ratio Required
CO	ppm	2000	300	50	6
NO_2	ppm	–	48	3	16
NO	ppm	1500	700	25	28
SO_2*	ppm	80	80	2***	40
soot	mg/m^3	1000	75	1.5**	50
EQI	–	–	232	3**	77

*0.20 per cent sulphur in the fuel.
**Proposed in French and Mildon.[6]
***Note that the TLV for SO_2 remains 3 ppm when used in the EQI expression defined below.

CO, formerly of great concern, now has become much less of a concern relative to other constituents as our knowledge of their health effects has increased: NO_2 is generally not a controlling constituent, although concentrations tend to rise at lower loads; NO produces moder-

ate concern; SO_2 has, perhaps, become the individual gas of greatest concern because its TLV has recently been reduced to 2 ppm – if the fuel sulphur is below 0.2 per cent, it is of less concern; the aldehydes are generally kept below their TLVs when the other constituents are controlled; and soot would appear to require the greatest fresh air dilution given a limit value of 1.5 mg/m^3.

Diesel soot is visible and has always been perceived as objectionable, and possibly noxious by miners. However, widespread concern for its relative effect on health has been clearly expressed only in the last decade. The Environmental Protection Agency (EPA) in the United States and the Canadian Environment Department both anticipate similar substantial reductions in soot emissions from surface diesels by 1991 relative to the present to neutralize the health consequences. Recent studies indicate that, while coal dust exposure was characterized by normally activated alveolar macrophages (as would be expected as a result of the invasion of a hostile particulate) the appearance of the microphage population on exposure to diesel soot suggested poisoning with consequent degradation in function.[7] I.W. French and Associates, contractors to CANMET, after studying 1,500 citations in the literature in 1978,[6] concluded that diesel soot was the most potentially hazardous component in diesel exhaust, suggesting an emphasis with respect to its control.

In general, when engine adjustments such as injection timing are made, the relative proportions of these various constituents change. Changes in these constituents due to malfunction, wear and maladjustment have been addressed in detail by Waytulonis[8] in a major effort performed on behalf of the U.S. Bureau of Mines Twin Cities Research Center in Minneapolis. Sometimes these changes compensate – as one constituent increases, another decreases. Further, derating an engine, i.e. reducing the maximum fuel rate, can reduce the soot emissions to below the 'smoke point', perhaps interchanging the governing constituents in the exhaust. Finally, addition of emission control devices can greatly alter the relative constituent concentrations.

These facts present all segments of the mining industry with a dilemma: by what criterion should adequacy of ventilation, i.e. air quality, be assessed? Such a criterion would ideally: (a) take into account the changing nature of the constituents, (b) assess comprehensively the toxicity of the exhaust constituents of major concern, (c) give credit for any air quality improvements allowing engineering economic tradeoffs to be made, and (d) allow regulatory agencies to prescribe ventilation consistent with

items (a), (b) and (c), and permit compliance measurements to be made.

At a meeting of the participants in Pittsburgh in 1980, the above aspects were considered, and it was decided that the Health Effects Index (HEI), then renamed the Air Quality Index (AQI), was the best criterion in existence by which to accomplish the above objectives and particularly to measure the progress of control technology developments on the reduction of overall diesel emissions.

At the same meeting, CDRAP decided to use the reduced emissions IDI Deutz engines* for application of emission control equipment because of their widespread use by the U.S. and Canadian mining industries. Although some R&D had already been carried out on the F8L714 engine, particularly the successful water-in-fuel emulsion work to reduce soot and NO, the 413FW series was chosen, because of its introduction in 1976, to ultimately replace the 714 version. Unfortunately, the water in fuel emulsion system did not prove to be effective when applied to the new 413FW series.

Except for minor beneficial changes, the relative concentration of the components of diesel exhaust are unaffected by dilution. Therefore, the French-Mildon criterion, intended for the evaluation of the diluted or ambient air, and known as the Ventilation Index, the Health Effects Index or, preferably, the AQI, can be used to evaluate the potential toxicity of undiluted diesel exhaust. When used for this purpose it is referred to as the Exhaust Quality Index (EQI). The French-Mildon literature study recommended a maximum value for the AQI of 3, above which some control measure was suggested. The mathematical expression recommended was:

$$\text{EQI or AQI} = \frac{CO}{50} + \frac{NO}{25} + \frac{RCD}{2} + \frac{H_2SO_4}{1} + 1.5\left[\frac{SO_2}{3} + \frac{RCD}{2}\right] + 1.2\left[\frac{NO_2}{3} + \frac{RCD}{2}\right]$$

where the ppm concentration for each gas is divided by its ACGIH TLV at the time of the formulation of the expression, and RCD is Respirable Combustible Dust having a limit of 2 mg/m^3. In addition, it should be pointed out that no constituent should be permitted to rise above its own individual limit, and that the sum of the

* Reference to specific brands, equipment or trade names in this paper is made to facilitate understanding and does not imply endorsement by the government agencies.

gaseous terms (CO, NO, and NO_2 relative to their respective TLVs) should be less than 1.

A minimum ventilation dilution ratio then can be calculated from $EQI/AQI_{max} = EQI/3$, and the minimum ventilation prescription equation is:

ventilation rate = undiluted dry exhaust gas rate × EQI/3.

Assuming sulphur in the fuel to be 0.20 per cent, and applying the above maximum values for the various constituents, produces typically an EQI value of 232, which, when divided by $AQI_{max} = 3$, yields a dilution ratio of 77. Therefore, the comprehensive EQI value, if employed, will govern ventilation prescription in most circumstances, rather than any of the individual constituents as indicated in Table 1.

There is a further development of this criterion, which separates the gas effects from the RCD effects by the formulation of two independent expressions, each with its own limit. The reader is referred to French and Mildon[9] for further elaboration. However, for the purposes of control technology performance assessment, CDRAP has continued to use the above single equation for consistency as both equation systems give virtually identical results from the standpoint of fresh air dilution ratio.

It should also be noted that the use of AQI = 3 in the single equation relation generally increases the prescribed ventilation rate for untreated exhaust only slightly relative to the use of the U.S. criterion: NO_x (as equivalent NO_2) divided by a limit of 12.5, as prescribed in Part 36.[2]

Therefore, with respect to the objectives stated above, this criterion takes into account the changing relationship of the constituents and assesses their overall effects. With respect to giving credit for air quality improvements, the addition of a device that is 90 per cent efficient in reducing particulate emissions, reduces the EQI by, say, 30 to 50 per cent depending on the circumstances, as is evident from inspection of the AQI expression. Therefore, a balance can be struck between realizing a total benefit in improved air quality from the use of such a device and maintaining ventilation as before on the one hand, and by realizing an economic benefit on the other hand by reducing ventilation to the appropriate level determined by the maximum limit of the AQI or of the individual constituents. Likewise, the buying of low sulphur fuel will have an effect that is easily assessed, etc.

Further, technology has been evolving, as described below, that permits the underground ambient assessment

of these major constituents using time-weight-average field measurement devices permitting calculation of the AQI levels. This, in turn, permits operators or regulatory authorities to evaluate the on-site performance of engines, and/or treatment devices or systems, in order to assure adequate levels of ventilation in a given circumstance. Thus all four requirements by which to evaluate progress listed (a) to (d) above are addressed by the use of such a criterion.

In addition to applying this AQI criterion for equipment performance determination, CDRAP has applied an additional assay – the Ames test. The mutagenic activity, as determined by the use of the Ames microbial assay, has demonstrated a high positive correlation with a number of other tests (*in vitro* and *in vivo*) of mutagenicity and carcinogenicity for the soluble fraction of diesel particulate.[10] Thus the Ames assay provides an inexpensive, convenient and relevant means of comparing diesel-derived contaminants from engine to engine and/or among treatment devices, permitting engineering judgements to be made regarding which R&D avenues to pursue, emphasize or discard.

Development of Exhaust Treatment Devices

Exhaust treatment devices, such as those developed in connection with the CDRAP program, can be applied to diesel emissions reduction in all types of underground workings: coal mines, other types of gassy mines, metal mines, and all other non-gassy types of underground workings. In the case of gassy mines, further developments to reduce the fire and explosion hazards are required. Traditionally, water scrubbing equipment has been employed in gassy mines to assist in avoiding this hazard. A decade ago, however, they were common in metal mines. In this connection, the original 1977 CANMET contract with the Ontario Research Foundation, described by Lawson and Vergeer,[11] detailed, evidently for the first time in the published literature, the performances of two then-current water scrubbers and a once-through catalytic purifier, all employed in metal mines. The scrubbers removed a respectable 40 to 65 per cent of the sulphur oxides (SO_2 and SO_3 – an important point to note in view of the recent TLV reduction for SO_2 from 3 to 2), but only 30 per cent or so of the soot. The catalytic purifier reduced 90 per cent of the CO to carbon dioxide (CO_2), but converted significant amounts of the SO_2 to SO_3 and NO to NO_2 (SO_3 and NO_2 are the more toxic forms). These early results suggested that there was room for improvement, particularly in the capture of soot.

Consequently, control technology development work was begun.

As part of this development program, a CANMET Research Agreement with the University of Waterloo was implemented to study materials by which soot could be filtered from diesel exhaust. This study continued for three years (1977-79), and showed that six materials were potential candidates. The USBM and CANMET studied the two most promising materials by the building and in-house testing of prototype systems, with modest success.

At this point, the Corning Glass Works representatives approached CANMET and the USBM to assess the potential of the ceramic wall-flow filter element as an underground diesel emission control system. Initial trials were successful. As the unit appeared to offer considerable advantages in terms of bulk, maintenance and regeneration potential, further development of the Waterloo materials was suspended.

These initial studies have subsequently led to the study by CDRAP of the following array of emissions reduction equipment options:

1 (a) a simple optimized baffle-type water scrubber design; and
(b) a high efficiency venturi-type water scrubbing system;

2. several ceramic wall-flow diesel particulate filter options (DPFs):
(a) simple DPFs for high exhaust gas temperature levels fostering unassisted soot auto-regeneration (combustion), resulting in acceptable equilibrium backpressures;
(b) the use of fuel additives in conjunction with the above DPF unit, significantly depressing the soot auto-ignition temperature and further widening the filter applicability or further ensuring untended, passive auto-regeneration of the filter;
(c) the use of noble catalyst-impregnated DPFs, further depressing the soot auto-ignition temperature relative to (b), useful particularly for low sulphur fuels. Recent preliminary work indicates negligible conversion of SO_2 to SO_3 for one noble catalyst formulation, perhaps eliminating this concern when fuels with moderate fuel sulphur levels are employed;
(d) the use of non-noble catalyst formulations, which, it is hoped, will demonstrate helpful soot ignition

temperature depression and similar insensitivity to fuel sulphur levels;

(e) the use of combinations of the above, such as applications of the simple DPF unit at non-auto-regenerating exhaust temperature levels, thus requiring some means of out-of-service regeneration such as is possible with the addition of auxiliary heat [for example, the face heater described in (12)];

3. a wire mesh catalytic trap oxidizer (CTO) filter unit (13);

4. exhaust gas recirculation (EGR) for NO control in connection with DPF use (14);

5. water-in-fuel emulsions for NO and soot control;[15] and

6. emissions effects on varying types of fuels and emulsions.[16]

The following sections describe highlights of the first two development thrusts. For the remainder, the attention of the reader is directed to the references indicated at the end of each item.

Water Scrubbing Systems

In-house CANMET assessment of commercial water scrubber performance over several years indicated a variation from 10 to nearly 50 per cent removal of soot. Further, scrubbers built to some non-Canadian specifications were often either heavy or costly to import, or both. Because of this fact, the Beaver Construction Group approached CANMET in 1981 to design and test a series of simple, low-cost, baffle-type, flameproof water scrubbers. These were to be used to drive the development heading to the Donkin-Morien seam of the Cape Breton Development Company in Cape Breton, Nova Scotia.

The outcome was that design principles were established and two scrubber sizes were drawn, built and tested by Beaver, Hovey and Associates (1979) and CANMET in collaboration. Careful use of a water separation criterion resulted in a 40 to 49 per cent (maximum) soot removal efficiency plus other beneficial effects, including the absorption of some of the acid gases. The performance matched or exceeded the best of available scrubbers at reduced cost. Such performance may represent a limit for basic uncomplicated designs.

In 1981 CANMET scientists realized that momentum-transfer, and consequent impact of soot particles with water droplets in a water-injected venturi throat inserted into an exhaust system, could be optimized for soot capture using a mathematical model. This resulted in the design, manufacture and testing of a venturi system mounted in the exhaust system of a Deutz F6L 912W engine. This unit captured 70 per cent of the soot, some of the sulphur oxides and 19 per cent of the NO_2, utilizing a backpressure of 10 kPa. Such a performance reduces the EQI by a substantial 50 to 60 per cent depending on the backpressure, suggesting beneficial application to coal mine vehicles where the prescribed airborne soot plus coal dust levels are difficult to attain and in non-coal mines where humidity is not a problem.

Ceramic Filter Systems

The filtering element in such filters is a porous ceramic material, the configuration of which is shown in Lawson, *et al*,[17] Howitt, *et al*[18] and Dainty, *et al*.[19] The porosity can be varied, so that the degree of soot trapping can be tailored to the need and coupled with tradeoffs in size and shape, filtering surface area and soot-free back-pressure, etc.

The rapid optimization of the ceramic element size to the gas rates of six-cylinder and eight-cylinder Deutz engines, for a nominal trapping efficiency of 90 per cent, led quickly to several development directions, including underground tests described in Dainty, *et al*,[20] and to the option definition process of the above list. These option developments are described briefly as follows.

In essence, the successful application of ceramic filters depends on the capability of the filter to handle the collected soot: (1) over a useful operating period, and (2) in such a manner that the backpressure buildup does not jeopardize engine warranty or mine safety. Thus, methods for promoting and enhancing the handling/disposing of the collected soot were held in high priority by the CDRAP and were investigated. The method appropriate for the ceramic DPF is the combustion of the collected soot while it remains in the DPF. The most advantageous circumstances would be to have the collected soot burn off as collected, a so-called auto-regeneration.

Auto-regeneration of soot results from the inter-related effects of several parameters, including the amount of carbon deposited on the filter surfaces and in the pores, the oxygen content of the exhaust gases passing through

the ceramic element and, perhaps most important, the temperature of the exhaust gases. Cyclic dynamometer tests at ORF, simulating Load-Haul-Dump (LHD) machine operation, have approximately defined the average values of some of these parameters, as reported in Table 2.

Table 2 Ceramic Filter Regeneration Threshold Parameters

Option		Unassisted Filter	Additive Assisted	Noble Catalyst Assisted
Minimum average load	(%)	77	54	48
CO_2/O_2 concentrations	(%)	8.0/9.7	6.0/12.2	5.4/13.0
Fuel/air ratio	(−)	0.037	0.028	0.025
Average exhaust	(°C)	427	365	349
Temperature	(°F)	800	690	660

The application of these three regenerating options of Table 2 to specific types of vehicles powered by conventional four-stroke engines appears initially to be a question of exhaust gas temperature characteristic determination. Such tests have been completed in the field at INCO Limited.[21] These confirm the above LHD dynamometer results for the unassisted auto-regenerating filter from the standpoints of average exhaust temperature and also the necessity of temperature excursions in excess of the 500°C (932°F) soot ignition temperature for sufficient periods to initiate combustion.

There have been examples of runaway regeneration that have resulted in damage, i.e. melting through or channelling of the ceramic matrix of the filter, the metal can remaining unaffected.[22] This appears to have resulted when excessive amounts of soot are deposited in the filter and ultimately subjected to sufficient oxygen and temperature to produce continuous high intensity combustion. The result is that soot removal virtually ceases and filter pressure drop decreases to a lower value with little immediate safety hazard.

The INCO experience[21] indicates that high exhaust gas temperature operation, which fosters continuous regeneration, maintains the backpressure at an acceptable equilibrium limit of 4 kPa (20 in H_2O) for a Deutz F8L 714 engine. Under these conditions the filter neither self-destructs nor results in apparent significant thermal overstressing for periods up to 1,830 h of operation. The key to safe operation seems to be the limiting of the amount of soot in the filter. To limit the amount of combustible material, and thus foster filter integrity, it is prudent to mount a backpressure sensor before the filter

and arrange for a signal to illuminate a dash light when the backpressure is constantly in excess of a given upper limit, say 7.5 kPa (30 in H_2O). Unreported in-house CANMET experiments using a Deutz F6L 912W engine in connection with electric face heater development studies showed that soot ignition did not occur when a filter loaded to a 5 kPa backpressure level was heat-soaked at high exhaust temperature (but below the soot ignition temperature) and suddenly exposed to the high oxygen concentration associated with low speed idle conditions. It should also be noted that the use of additives or catalysts depresses the soot ignition temperature significantly, appreciably reducing the likelihood of soot accumulation. While it appears that the type of operation described above results in safety thus far, it is hoped that R&D will be undertaken to further define the parameters of safe operation, and that ceramic element design can be developed to help limit this type of problem.

In addition to safety considerations, extensive studies of exhaust treatment devices have been made both in the laboratory and in the field to indirectly gauge the health effects of diesel pollutants. These studies have been in the form of polynuclear aromatic hydrocarbon (PAHs or PNAs) analyses to determine the levels of known carcinogens, and Ames mutagenic assessments to flag their apparent collective carcinogenic potential relative to presently applied technologies. This latter aspect is detailed in Mogan, *et al*,[10] which indicates that a significant reduction in Ames mutagenicity levels occurs as a result of the use of novel emission control options such as those developed in connection with the CDRAP program.

As a result of this multi-faceted examination of these filtration systems, it is estimated that they can be applied to most LHD machines and a portion of haulage trucks (say a total of 50 per cent of the underground fleet), thus coping with by far the greater part of diesel vehicle soot contributions to underground environment contamination. Other applications would require periodic induced regeneration, either off or on the vehicle, prompted by a panel-mounted warning light, indicating backpressure buildup due to soot deposition.

Development of Field Environment Assessment Techniques

The U.S. Bureau of Mines has had an on-going environmental assessment program in place for some time, involving study of such concepts as: (a) tube bundle continuous monitoring,[23] (b) in-mine array of sensors relaying signals to the surface, (c) a Mine Air Quality

Laboratory (MAQL) for in-mine deployment where possible,[24,25] and (d) a portable analysis equipment array carried into the mine to monitor environmental contaminants in order to provide both time-weighted-average (TWA) and instantaneous levels of five contaminants.[26]

While each of these can be related to mine diesel technology, the latter two have been of most assistance to the CDRAP diesel program. The MAQL has been and continues to be employed by Michigan Technological University (MTU) under contract to the Bureau of Mines to evaluate some of the options listed above. Among these are the catalyst and fuel additive filter options installed in a Wagner Mining Equipment Company Scooptram. The venturi water scrubbing system and some ceramic filter options are being evaluated in the same facility, employing an LHD machine furnished by the Jarvis Clark Company Limited, supported by the Mining Industry Research Organization of Canada (MIROC).

This work is performed in an underground experimental mine heading in Hancock, Michigan, designed to duplicate real work conditions for an LHD mucking cycle, while at the same time permitting careful control of all the experimental conditions relating to ventilation, multicomponent sampling, analytical precision and vehicle cycle repetition, so difficult to realize in the dynamics of an operating mine. Results of this option testing program are described in Carlson, *et al.*[25]

The portable analysis system has been developed by MTU and employed by an MTU team and/or a CANMET team for a number of mine environmental assessments, including coal, salt, nickel, zinc and potash mines, to evaluate the impact of new diesel emissions reduction concepts on the environment and to evaluate the contaminant levels. Some aspects of four such studies are detailed in Dainty, *et al.*[20]

The result of applying these portable systems is the determination of the time-weighted-average values (TWAs) of CO_2, CO, NO and NO_2 gases (in % of ppm) plus the respirable combustible dust (RCD) in mg/m_3 for however many sampling stations are employed in a given investigation. These are the necessary values for characterizing the comprehensive toxicity of all the major components of diesel exhaust using the AQI described above, and relating such values to the CO_2 concentration. Instantaneous, real-time concentrations of the four gases are also determined at one sampling station for confirming comparisons to the TWA values and for assisting in the definition of the variations of the machine operating cycle.

By such field measurements, comparative evaluation of the air quality can be made with and without control devices, for example. The studies reported in Dainty, *et al*[20] indicate environmental improvements due to ceramic filter application of 35 to 65 per cent relative to catalytic purifiers as measured by the AQI criterion.

There are several important generalizations that emerge from this detailed environmental assessment work, a summary of which follows:

1. Examination of voluminous constituent concentrations in the MAQL has led to the conclusion that the CO_2 concentration is a direct surrogate for all the other measured pollutants. This is most useful for an engineering approach to environmental control, which approach is described in relative detail by Schnakenberg[27] of the Pittsburgh Research Center, and Daniel[28] of the Washington D.C. Office of the Bureau of Mines, Department of the Interior.
2. TWA values of NO_x and NO_2 are presently determined by the easy in-mine deployment of Palmes diffusion-type samplers. These simple devices can, when care is exercised, produce an in-sample variation generally well within plus or minus 20 per cent of the mean and levels that compare well with integration of constituent concentrations derived from real-time traces generated by portable laboratory-type analysers.[20] The Palmes sampler approach is acceptable, but it requires considerable pre-test preparation time and post-test analysis time plus some laboratory analytical equipment. TWA values of CO_2 and CO are determined by bag sampling and post-test analysis using the same type of portable laboratory zero/span analysers, likewise involving some additional time before the answer emerges. Long-term stain tubes (CO_2, CO, NO_x, and NO_2), plus associated pumps, are now available to provide immediate answers at the end of the testing period without further effort. While pump failure and NO_2 sensitivity are present difficulties,[20] it would appear that further development of long-term stain tubes will reduce the effort to make spot AQI and individual constituent assessments underground by an estimated 40 per cent relative to the use of the present array of equipment.
3. Soot, assumed to comprise 75 per cent of the RCD, is composed of solid carbon plus varying amounts of adsorbed hydrocarbons. The hydrocarbon fraction has been a source of difficulty in assessing the efficiency of ceramic filters in the underground environment.

Dynamometer-derived efficiencies of the order of 90 per cent were not confirmed by the results of a number of underground assessments that suggested a 40 per cent or so level of filtration efficiency. MTU personnel were asked to look into this lack of agreement. Preliminary considerations, quoted from an MTU progress report showing that 'half an ounce of oil (leakage) per hour could offset the test results and lower the MAQL (emissions) system efficiencies from 78 per cent to 36 per cent due to this additional particulate source', were confirmed in Carlson, *et al.*[25] It appears that leakage of fuel, hydraulic oil, etc. onto hot surfaces can add substantially to the air-borne contributors to the RCD measurement in addition to exhaust-generated soot – a point that must be kept in mind, not only when field assessments are made but also as a source of unwanted respirable particulate matter and hydrocarbon vapours, even though the limits for the latter may be higher than that suggested for soot.

4. Over reasonable periods of time, assuming proper maintenance and small variations in the vehicle duty cycle, the components of diesel exhaust remain in relatively constant proportion with one another and CO_2. The AQI for such periods is therefore in relatively direct and constant proportion to the CO_2. Consequently, easy measurements of CO_2 can then provide quick estimates of the suitability of the ventilation, keeping in mind the following proviso. Changes in emission levels due to engine wear, fuel system adjustments, malfunctions, etc. can change the relativity of the various constituent levels of CO_2. Thus, undiluted exhaust levels of the constituents and CO_2 should be monitored from time to time to determine such changes, re-establish the appropriate dilution ratio and adjust the ventilation accordingly. In the short term, assuming no significant changes in engine emissions or ventilation rate and an AQI = 3, the easily-measured CO_2 control limit can be determined by using the ratio of the measured CO_2 and AQI values for the ambient environment. As long as the CO_2 remains at or below this control limit, the AQI can be assumed to be 3 or less. For example, during one filter evaluation described in Gangal, *et al*,[29] an AQI value of 0.51 and a CO_2 value of 0.05 per cent were determined for the LHD operator's station. Because the AQI, of all of the possible limiting items, was closest to its limit of 3 (both the SO_2 and the NO concentrations were similarly close to their respective limits), the ventilation could theoretically be

reduced by a factor of 6 to produce a CO_2 value of 0.3 per cent (i.e. 0.05 × 3.0/0.51), assuming that other difficulties would not result.

Therefore, suitably accurate measurement techniques are available to assess all the constituents normally necessary for environmental assessment. While some aspects of these techniques presently require time and capital, developments in the near future should minimize both of these aspects. Once such measurements are made, they will facilitate the making of engineering judgements regarding ventilation acceptability by virtue of the direct relationship of easily-measured CO_2 with each of the toxic constituents and/or the AQI, ratioing each to its respective limit and keeping in mind the assumptions stated.

Conclusions

Retrospect and Prospect

It has been estimated that there are some 5,000 to 6,000 diesel vehicles in the underground mining fleet in all types of mines in the U.S.A. Similarly, there are between 3,000 and 4,000 such vehicles in underground service in Canadian mines.[30] In very approximate terms, this means that the North American mining industry has a substantial capital investment of between 0.5 and 0.75 billion dollars directly in such equipment, to say nothing of the indirectly related investments. This substantial sum suggests, on the one hand, that such equipment might have a minimum life of say, 10 years, perhaps longer before writeoff. At such a time it would be replaced when and if superior, proven technologies emerge that can be applied. Therefore, the application of the control technology produced by this program would appear to be suitable for a commensurate period of time. It is likely, on the other hand, that a residual number of diesel vehicles will always be required for some mining tasks by virtue of their flexibility of operation. Therefore, emissions technology may have a considerable lifetime of applicability in excess of the 10-year period.

It would also appear that sharper definition of the health effects of diesel emissions, as well as the development of reduced emissions technologies, can reduce the legitimate fears and lessen the perception on the part of some members of the mining community of the necessity of discarding diesel equipment technology, making it more feasible to extend the lifetime at least to the point of investment recovery and perhaps longer.

Specific Outcomes

There is a view expressed, in connection with the listing of technologies necessary to meet the 1991 EPA soot standards for surface diesels vehicles, that engine development has already contributed the maximum possible to the reduction of emission levels with no significant engineering breakthrough in sight. Therefore, it is assumed that major reductions can only come from exhaust treatment, fuel alterations, etc. To this end, the CDRAP collaborators have advanced two water scrubbing systems (venturi and baffle types), suitable particularly for coal mines, to the demonstration and application stages, respectively. In addition, mainly for non-gassy mines, six ceramic filter options, including EGR, have been studied as listed above. These are variously applicable depending on the circumstances. Extended field durability tests of approximately 1,830 h in service suggest that filtration is a strong option with which to either reduce the toxicity of the environment or reduce costly ventilation, or to strike a compromise, depending on the stance taken by the appropriate regulatory authority. It is estimated that these filter options are applicable to up to 50 per cent of the underground diesel fleet, of which the contribution to the underground contaminants is thought to be 70 per cent of the total.

The AQI/EQI concept, while not presently promulgated as a standard, does provide a means of assessing the comprehensive toxicity of emissions. Use of the AQI as a ventilation criterion generally only slightly increases the ventilation prescription resulting from use of the $NO_x/12.5$ criterion. In general, the order of ventilation-governing items is: (1) the AQI, (2) soot concentration, and (3) SO_2. In cases where the fuel sulphur exceeds 0.3 per cent, SO_2 may be the governing constituent.

Therefore, use of the EQI/AQI concept and the principle that CO_2 concentration is an easily-measured surrogate for the AQI or each contaminating constituent rationalizes choice of engine, treatment option selection, ventilation system and mine design, and makes possible the ultimate closing of the loop, i.e. the establishment of automated control of ventilation and related systems, based on continuous sensing of CO_2 or the individual contaminants and the ventilation parameters in order to effect considerable operating cost reductions.

The Power of Collaboration

The willing co-operation of the various segments of the mining community in North America has resulted in the numerous significant developments described above. The large number (approximately 31) of collaborating organizations attests to the power that has been brought to bear on the emissions problem by this active co-operation of all parties, public and private, participating in the CDRAP programs. Gratitude for these efforts is extended to all the participants.

Résumé

Le comité consultatif de recherche en diesel a été créé en collaboration pour résoudre un certain nombre de problèmes, notamment : déterminer un critère permettant d'évaluer la toxicité générale des principaux composants des gaz d'échappement du diesel, faire la recherche et le développement pour ajouter de nouveaux dispositifs au système d'échappement, étudier de nouvelles techniques visant à réduire les émissions produites par les moteurs diesel, évaluer leurs effets sur le milieu souterrain et élaborer une stratégie visant à améliorer l'environnement minier, à réduire les coûts de ventilation, à accroître la productivité et à augmenter la sécurité sous-terre, en fonction des conditions propres à chaque situation. Ces problèmes sont exposés plus en détail dans l'article qui suit.

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Health Surveillance Data*

Summary

An adequate health information system is an essential part of worker health surveillance. In Canada, as in most western industrialized countries, the necessary systems have not yet been developed. This paper enumerates the principles and the factors that should be considered, as well as the benefits that may be derived from good information systems.

An adequate health information system is an essential part of worker health surveillance. This is true for the individual, the employing organization and the nation.

In Canada, as in most western industrialized countries, the necessary systems have not yet been developed (see Appendix). This contrasts with information on infectious diseases in the community as a whole, probably for historical reasons. In our private enterprise economy and with our emphasis on freedom and individual choice the regulatory approach to development of a worker health information system is sparingly used. Therefore, this task force advocates an approach that may be used in either a voluntary or a regulatory context; namely, the proposal of a series of objectives concerning worker health information and the suggestion of the necessary principles to be employed in reaching one or more of them. These principles have been designed to help in the future co-ordination of such information while protecting the individual's rights.

This realistic approach will hold good, whatever degree of political and social priority is accorded to worker health in the future.

Objectives

1. To acquire information concerning health examination results and environmental exposures for individual workers.
2. To evaluate preventive measures used by individuals and by groups.
3. To follow disease trends by occupation, by occupational sector, by exposure history and by work method.
4. To acquire new knowledge concerning occupational diseases and injuries.
5. To detect hitherto unsuspected health effects related to occupations.

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Data System Guidelines

In order to achieve these objectives, the following principles or factors should be considered:

I. Desirable Types of Information

A. *Worker Identification*
An identification number is helpful but not essential because other information considered together may identify with reasonable certainty.
(i) Full birth name – first given name, second given name.
(ii) Birth date.
(iii) Birthplace (country or province).
(iv) Mother's maiden surname, or own name if married female.

Other helpful items include sex, marital status, address, place of residence, ethnic origin, social insurance number (SIN), provincial health insurance number, driver's licence number, unemployment insurance number.

B. *Worker Disease Susceptibility* (including pathogenic co-factors)
(i) Past and present illnesses, disabilities and injuries.
(ii) Inherited factors.
(iii) Reproductive co-factors.
(iv) Lifestyle – e.g. drug abuse, including smoking and alcohol.
(v) Spare time occupations and hobbies.

C. *Relevant Clinical Tests* – e.g. pulmonary function tests, audiograms.

D. *Biological Monitoring* – e.g. blood lead estimations.

E. *Morbidity* – e.g. worker health care records, sickness absence data, primary care data from health insurance records and hospitalization records.

F. *Mortality*

G. *Specific Hazards or Exposures in the Workplace* – e.g. chemicals, radiation, noise.
(i) Nature.
(ii) Duration.
(iii) Protective equipment used.

H. *Exposure Measurements*
(i) Site of sampling, e.g. use of personal worker samples or area sampling.
(ii) Method of sampling and analysis.

I. *Occupation*
(i) Previous and present job titles, with periods spent in each and name of employing organization.
(ii) Location in the plant.

J. *Population-at-Risk Records*
This information may be obtained from employee records, special registers, union records, etc. It is necessary in order to calculate disease rates and risks.

K. *Reproductive Information*

II. Desired Qualities in Data Storage, Retrieval and Analysis

A. *Machine Readability*
The data collected in a format suitable for ease of transfer to a computer and/or processing by a computer.

(Note: The use of personal files that are not machine-readable, while useful in a single organization for the care of an individual while he/she is a member of that organization, tends to lead to difficulty and high cost in the retrieval of data. Card index systems are only useful when the numbers involved are small.)

B. *Confidentiality*
Access should be restricted to bona fide users.

C. *Continuous Up-Dating of Population Groups*
Leavers should be flagged or removed so that current populations can be known.

D. *Facility of Linkage*
(i) Within a system or organization, e.g. linkage between health information, exposure data and duration of employment.
(ii) With other systems, e.g. linkage between information on similar groups of employees in different companies, especially where common occupations are usually present in small groups.

E. *Preservation of Chronology*
This is desirable with respect to exposure times and illness, e.g. this would permit radiation dosage patterns to be preserved to permit the evaluation of delayed effects and latency as in occupational cancer.

F. *Economic Feasibility*
Computer data systems require skill and initial expenditures to set up, but are indispensable for handling large amounts of information economically. *Ad hoc* epidemiological studies without such a data base are very expensive on a *per capita* basis.

G. *Reproductive Information*
e.g. Ability to trace offspring, simple fertility information such as birth of children.

H. *Special Registers*
These have proven valuable for the investigation of specific diseases, occupations or population groups.

III. The Guidelines Relevant to Achieving Individual Objectives

The following comments are designed to assist users in selecting the guidelines relevant to their particular needs.

A. *To Acquire Information Concerning Health Examination Results and Environmental Exposures for Individual Workers*
Comprehensive information should be collected over the worker's lifetime and should include personal identification information with relevant health, job and exposure information. It should be preserved between job changes with suitable safeguards of individual rights, yet be retrievable at reasonable cost. It need not be machine readable, but if a special register is applicable to this particular worker's exposure then this would be helpful, as, for example, in the case of asbestos workers.

B. *To Evaluate Preventive Measures Used*
The nature, timing and degree of the hazard of interest should be recorded with the type of protective measure (including equipment used).

Suitable periodic examinations should be recorded, with their timing. The information should be preserved between employments and either transferred to a new employer or held in a suitable central agency. Internal

linkage between exposure and health data, and longitudinal linkage is important.

C. *To Follow Disease Trends by Occupation, by Occupational Sector, by Exposure History and Work Method*
These objectives imply pooling of information between organizations, at least for some purposes, e.g. the oil and gas industry or occupations such as sewer maintenance. The information should be machine-readable; the health evaluation data and the exposure information or job descriptions should be standardized in quality and nature so that like can be compared with like.

Precision of description of exposure history, including timing and whether continuous or intermittent, is desirable. Where work method is being studied, such factors as apparatus, technique, engineering protection, personal protection and training level should be recorded.

D. *To Acquire New Knowledge Concerning Occupational Diseases and Injuries*
This ambitious, but important, role lends itself to the employment of modern data handling systems. In most cases the advice of an epidemiologist and/or biostatistician is advisable at the earliest planning stage when detailed research objectives are being defined.

E. *To Detect Hitherto Unsuspected Health Effects Related to Occupations*
In the past the occurrence of clusters of cases, often with a geographical background, led to valuable advances by the recognition of distinctive forms of disease related to occupation. This is not an efficient method of detecting chronic occupational diseases that resemble common ailments or in recognizing the effects in scattered groups of workers or their offspring or for delayed effects.

The detection of clustering of cases of diseases, without relying on geographical grouping, is made possible by the use of effective data handling systems. Identification of clustering by hazard, industry, occupation and specific toxic exposure, age and sex should be sought by systematic data collection in association with suitable worker population sampling.

Indices of health, in addition to those usually sought, should be considered and developed. Examples are: indices of wellness, fertility, congenital abnormalities in offspring, spontaneous abortion rates, behavioural abnormalities and productivity.

IV Benefits of Good Information Systems

A. *Disease and Hazard Identification*
This allows corrective action to be taken to prevent or limit disease effects by means of engineering control of the environment and/or protective equipment and/or hygiene facilities.

B. *Assistance in the Diagnosis or Exclusion of Occupational Disease*

C. *Evaluation of Environmental Control and Recognition of Failure*

D. *Verification of Acceptable Exposure Levels*

E. *Recognition of New Hazards or Absence of Hazards*

F. *Ongoing Program Evaluation and Identification of Health Service Needs*

G. *Early Planning of Corrective Actions*
This would tend to avoid disruptively sudden process changes.

H. *Provision of an Ongoing Data Base of Good Quality*
This would reduce the need for *ad hoc* epidemiological investigations but would assist in their successful completion if they were conducted.

Appendix

In the course of its investigation, which led to development of the approach and the guidelines suggested, the subcommittee on data collection visited various organizations, including Health and Welfare Canada, Agriculture Canada, the Department of National Defence, Statistics Canada, Dofasco and members of the Occupational Health Program at McMaster. The Health and Safety Commission of New Brunswick, the WCB of Ontario, the Ministries of Health and Labour of Ontario and the Health and Safety Executive in the U.K. were communicated with. Authorities in Sweden, Israel and the Federal Republic of Germany were also corresponded with.

A selected bibliography was compiled after an extensive literature search.

A detailed and extensive study entitled 'Evaluation of Existing Data Sources of Occupational Injury and Illness Statistics' was commissioned by the U.S. Occupational

Safety and Health Administration and published by the U.S. Department of Health Education and Welfare in 1977. The evaluation of occupational health data sources in the U.S.A. was the main focus of the report, which included the following statement:

> 'Preventing those environmental conditions that affect human health is one of the most cost-effective strategies for preventing disease and impairment . . . occupational exposures to specific materials, because they are usually more intense and better defined than community exposures, can indicate agents that negatively affect health in the community – causing disease and impairing health or performance.
>
> National data sources were reviewed, and in most of them it was considered that the scope and degree of coverage of occupations was patchy, and inappropriate sampling techniques were employed.'

This comprehensive review and major study was a valuable source of information. The title of a U.S. Congressional Committee Report in October 1984 (Union Calendar No. 641; House Report 98-1144) is self-explanatory: 'Occupational Illness Data Collection: Fragmented, Unreliable, and Seventy Years Behind Communicable Disease Surveillance.'

In North America a few good systems with record linkage have been established in private industry in large organizations. We are not aware of any western industrialized country having a good comprehensive occupational health data system except in limited sectors with a narrow focus, such as the radiation exposure of radiation workers.

The Canadian legislation concerning health protection of the public and of workers with respect to ionizing radiation provides an interesting exception to the predominantly provincial system with respect to virtually all other occupational and environmental hazards. This has been associated with the setting up of a national machine-readable health data system with respect to this sole hazard. The radiation exposure of all designated radiation workers is regularly updated, with the timing of exposure recorded. This is linked with mortality information on a national basis. This system combines individual records of exposure and information about the relationship between the exposure and also the cause of death of groups.

The system has the defect that it omits lifestyle information and non-radiation occupational health data.

These examples, however, demonstrated that well-linked machine-readable occupational health data systems can be established in Canada and also the practicability of establishing them initially in defined high-risk occupations where the need is recognized.

We have found no evidence of comprehensive linkable occupational health data collection in most large industries, in small industry or in farming in Canada.

Résumé

Il est indispensable d'avoir un bon système de renseignements sur la santé pour pouvoir surveiller la santé des travailleurs. Or, au Canada, comme dans la plupart des pays développés, ce système n'a pas encore été mis sur pied. L'article qui suit dresse une liste des principes et des facteurs qui devraient être examinés ainsi que des avantages que présente un bon système de renseignements.

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The Control of Occupational Health Hazards in Construction

Summary

The options for the control of occupational health hazards in the construction industry are reviewed. It is concluded that the traditional solutions in fixed industry, using substitution, ventilation, process modification and administrative controls, are inappropriate for construction sites, and that control by procedure is more appropriate. The detailed and uniform specifications make it easy for regulatory agencies to assess compliance.

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Construction workers may be exposed to a wide variety of toxic materials about which they know very little and over which they have little control. Construction employers, for the most part, are not much better informed or knowledgeable than their workers. This presents some major difficulties from both educational and regulatory perspectives.

The lack of knowledge, as well as the other features unique to construction, make the application of traditional industrial hygiene control strategies inappropriate. A new control strategy therefore had to be developed.

The Construction Safety Association of Ontario (CSAO) brought forward the concept of 'control by procedure' as a workable solution for both the construction industry and the regulatory agencies.

Essentially, 'control by procedure' spells out specific controls for different operations. Where the hazard potential is similar and the control options are basically the same, several operations can be classified by type with standard controls. This often results in several different control option paths for any given material (e.g. asbestos).

Before explaining regulation by procedure in more detail, it is important and worthwhile to understand some of the special characteristics of the construction industry.

There are approximately 264,000 workers available for work in the construction industry in Ontario[1] representing 155,000 person years of work in 1985. This work force is employed by over 30,000 individual firms[2] on a wide variety of projects. Because many construction workers are hired only on a job-by-job basis, there is a significant turnover rate in the industry. It is not uncommon for a worker to work for several different employers in the course of one year. This highly mobile work force poses obvious logistical problems in training, record-keeping and medical surveillance.

Another unique feature of the construction industry is the everchanging worksite. Factors such as wind, temperature and humidity can have significant impact on worker exposure to toxic materials. In addition, constant changes to the man-made environment as construction proceeds and the introduction of new hazards at different stages of

the process can make personal exposure monitoring meaningless on a worker-specific, task-specific, site-specific basis.

A third feature to consider is the industry's lack of control over the materials it uses. Clients, architects and engineers specify the type of materials to be used, often without due regard for the hazards involved in their application, and these specifications form part of the contract. The classic approach to solving many occupational health problems through the use of safer substitutes is often not possible in construction since it could void the contract. A related problem is the fact that products with superior performance characteristics desirable in the finished structure often contain well recognized toxic materials (e.g. chromium in stainless steel, coal tar pitch in roofing, epoxy and polyurethane compounds in paints and coatings). While these products do not generally pose any hazard for the client, the way in which they are applied, installed or used by construction workers can present serious risk of overexposure.

The fourth major feature of construction is the one alluded to earlier – the general lack of knowledge and skill to assess and understand occupational health issues. In fixed industry, an in-house expert or resource person is usually available or can be hired as a consultant to evaluate the work environment and assist in solving occupational health problems. This is relatively easy for stable environments in which the materials, processes and other conditions remain unchanged for long periods of time. In construction the factors already described make worker education and evaluation of the everchanging environment very difficult. Lack of in-house expertise regarding chemistry, physiology and toxicology can make even the relatively simple task of deciphering a supplier's material safety data sheet a fruitless exercise. The fact that the vast majority of construction employers simply do not have the personnel to properly evaluate and control health hazards and still perform their primary duties as superintendents, estimators, planners or foremen must be accepted as a prevailing condition in the construction industry.

While there are other obvious differences between construction and fixed industry, these four factors pose the major obstacles in applying traditional solutions to occupational health problems.

Let us examine several aspects of the traditional approach for comparison with the 'procedural' approach.

Exposure Evaluations

Traditionally, industrial hygienists conduct air sampling or other exposure monitoring to determine whether or not the performance standard of 'X' milligrams per cubic metre or 'X' parts per million is being met.

With stable environmental conditions and relatively consistent materials and processes monitoring can be fairly easily done, and is required initially and repeated if and when the process or the environment changes. On a construction project weather conditions can shift markedly from hour to hour and from day to day, the man-made environment can significantly change even faster. For these reasons, worker-specific, task-specific, site-specific sampling is ineffectual.

On a construction project where there may be a wide variety of hazards to evaluate, the instrumentation and the trained personnel required to conduct sampling and maintain equipment are simply not available.

To specify a 'performance standard' for construction exposures would be self-defeating. Employers would not generally understand the significance of that standard, and neither supervisors nor workers would be able to determine whether exposure was over or below acceptable limits.

From a regulatory perspective, enforcement and prosecution under such a standard would be almost impossible. The OSHA compliance guide indicates the number of samples required to prove non-compliance. Given the nature of construction, it is quite likely that an operation would be completed and workers would move on to another area before even the first results were available, let alone enough data for a successful prosecution.

The approach CSAO has taken has been to examine the exposures to given materials designated by the Ministry of Labour and to determine exposure profiles for the types of operations considered important and requiring study. Then, a comprehensive literature search is undertaken, including access to computerized databases, to retrieve any relevant information in the public domain.

Based on the results, an evaluation of the operation(s) is conducted. It may take the form of specially prepared and tailored exposure conditions or may simply sample actual workplace situations. One approach used successfully is the creation of a controlled 'worst case'. A situation is set up to generate an exposure that duplicates the worst condition likely in construction. If results indicate no likelihood of overexposure under these very adverse conditions, then the chance of generating a significant exposure on a construction project is very

remote. If results indicate an overexposure, as they often do, then an upper limit for the exposure profile has been defined.

Depending on the material and process involved, it may be possible to extrapolate from the data and determine the likely exposure conditions prevailing under different situations. If this is not possible, other evaluations are conducted under more representative conditions.

With limited resources in this area it is difficult to generate large data sets. However, information generated is valid, and, in most cases, it is the only information available regarding construction exposures to the material in question.

It is disquieting to note that virtually nothing has been published concerning the exposure of construction workers to even the most common and well understood health hazards, such as silica, asbestos, noise and chromium.

Control Options

Traditional solutions to occupational health problems in fixed industry include the use of substitutes, enclosures, ventilation, process modification and, finally, worker protection and administrative controls.

Let's examine each of these control options and their suitability to construction.

(a) Substitution

The choice of materials used on construction projects is often made by the client or the client's representative – the architect or engineer. Contractors cannot substitute other materials equally suitable but less toxic. Some major changes have occurred, e.g. the substitution of asbestos with calcium silicate and fibreglass materials. However, this option has distinctly limited application to construction projects.

(b) Enclosures

In fixed industry it is quite often reasonable and practical to enclose a hazardous operation. Enclosures on construction projects are often used to isolate a hazard from other areas. However, construction workers are often required to work within the enclosure in intimate contact with the hazard, e.g. enclosing a sandblasting site to prevent secondary exposures to innocent bystanders. While this limits the exposure potential for bystanders, it drastically increases the exposure potential for workers inside the enclosure.

(c) Ventilation

Local exhaust ventilation is a good control option for a variety of hazards. In fixed industry it can be used effectively and justified in a variety of ways.

On a construction project the use of ventilation, especially local exhaust ventilation, is distinctly limited and applicable only to a small number of activities, e.g. controlling exposure to welding fumes. Exposure during paint spraying in a plant may be controlled by using a special booth with adequate ventilation. Exposure from painting walls in a building under construction, however, may be difficult to control with ventilation due to the large surface areas involved and the limited number of ventilation openings available. General dilution ventilation is often used fairly effectively on construction projects and is a control option when working out of doors.

(d) Modification of the Process

Although it is possible to alter methods to make them less hazardous, the modified process may not be well suited to highly mobile and changing worksites. The use of robotics or other mechanical aids in performing work has merit in many applications, but few in construction.

(e) Worker Protection

Traditionally, industrial hygienists have viewed the use of personal protective equipment as a last resort. But given the fact that other control options generally have little application to construction, a reliance on personal protective equipment as an adequate safeguard for the worker must be given serious consideration.

Although there are obvious problems in the use of respirators, hearing protectors, gloves, barrier creams and other protective equipment, an adequate level of health protection can be achieved with proper use and maintenance of the equipment.

CSAO's approach has often been to provide more protection than what may be justified on the basis of air sampling data alone. However, this conservative approach builds another factor of safety into the control program. A significant amount of training is required to ensure that personnel understand the purpose, use and maintenance of their equipment.

This is seen as a primary objective of the Construction Safety Association of Ontario. Training requirements have therefore been specified in the codes and incorporated in the legislation.

(f) Administrative Controls

There is little application for administrative controls in the construction industry. Moreover, CSAO tends to disagree with such an approach because it does not control the hazard – it merely exposes more people to some risk. Controlling the hazard wherever possible is preferable.

A critical feature of any occupational health control strategy is education. The Construction Safety Association of Ontario provides educational services to both labour and management in the industry. Unfortunately, there is considerable confusion and concern regarding occupational health hazards in construction. Information that is fairly basic, e.g. information on the material safety data sheets, often overwhelms construction readers since they understand neither the terminology nor the significance of physical characteristics such as melting points, boiling points and vapour pressures. A tremendous job exists in broadening the range of knowledge and awareness in the industry and developing expertise within firms, trade unions and larger employer groups.

A final issue to address is medical surveillance. In a fixed industry, with low labour turnover and facilities for central record keeping, the issue of medical surveillance is easily addressed. However, on a single construction project or with a single construction employer the workforce is highly mobile with turnover rates as high as 600 per cent annually. This makes record keeping a horrendous logistical problem. The worker may work in Thunder Bay one month, Kingston the next month and then in Sarnia for several weeks. It is highly unlikely that records will follow the worker. The worker may also be exposed to a wide variety of chemical and physical agents that may affect health.

Pre- and post-employment physicals under such conditions are obviously difficult to arrange and record. For example, a worker exposed to asbestos in an industrial setting should undergo medical assessment to determine suitability for employment in that area and also to monitor the status of health as the employment history continues. Part of this evaluation would include periodic chest X-rays. In the case of a construction asbestos worker who works for six different employers in the course of a year, it is unreasonable, and may itself constitute a health risk, to require six chest X-rays of that individual in a year. These issues must be identified and addressed in any discussion of medical surveillance.

Labour has voiced some significant concerns about the surveillance and record keeping of exposure in the hope that compensation claims will be adjudicated much more easily if documentation is available. Therefore, some central record keeping facility is required. What has been contemplated and, in fact, included in the construction asbestos regulation, is a central registry maintained by the Chief Physician, Occupational Health Medical Service of the Ministry of Labour. The Chief Physician will be responsible for compiling and maintaining a register of workers exposed to certain toxic materials, i.e. asbestos and silica, in the construction industry. Based on data submitted by employers and, in some cases by workers themselves, the Chief Physician will arrange a medical surveillance schedule to monitor the status of such workers. Although this is not a perfect solution, it may be the most realistic and effective approach for the construction industry.

Control by Procedure

Having reviewed the main features of the traditional approach, let us examine 'control by procedure' in more detail.

The first step is to assess the hazard potential associated with different materials or procedures. Secondly, to look at control options that are workable and effective as well as reasonable and practical. This may result in some additional air sampling to determine the adequacy of control options being suggested or specified. Quite often, one control is good for solving several different hazards. For instance, local exhaust ventilation can handle the contaminants present in welding fume, while dust suppressants applied through wetting can control a wide variety of dust hazards. Although limited, personal protective equipment would be specified on the basis of air sampling data, as well as very conservative protection factors derived from standard industrial hygiene resources. Thirdly, the administrative details required by the Ministry of Labour to apply and enforce the regulation must be addressed.

A significant feature of 'control by procedure' is that its detailed and uniform specifications provide a consistent basis for competitive bidding. Contractors who are bidding projects involving the use of certain toxic materials or certain hazardous procedures know exactly what controls are required and can allow for costs accordingly. Control by procedure also provides ready detection of hazards and verification of controls by relatively unskilled workers. If they are told that a certain type of enclosure

and a certain type of respirator should be used, and neither is available on the job site, they can quickly determine whether or not the regulation is being complied with and take appropriate action to correct the problem.

From a regulatory agency's perspective, a Ministry of Labour inspector simply has to look at the equipment and procedures in place to assess compliance. Highly skilled industral hygienists or sophisticated air-sampling instruments and analyses are not required to determine whether workers are adequately protected.

It is interesting to note that jurisdictions outside Ontario are interested in 'control by procedure'. Different organizations in the U.S. construction industry are actively urging OHSA to establish procedural rather than performance standards. The Construction Safety Association of Ontario views it as the most appropriate means of regulating worker exposures to toxic materials on construction or similar worksites. What is required now is a concerted effort to evaluate these hazards, since only a handful have been examined to date, and to quantify the exposure potentials. This should proceed as quickly as possible in conjunction with modifications to contemplated or existing right-to-know legislation as well as improvements in the requirements for labelling and material safety information. Any regulations in these areas must, of course, consider the features that make construction significantly different from other industries.

Résumé

L'étude porte sur le moyens de contrôler les risques de maladie liés au travail dans l'industrie du bâtiment. Elle en conclut que les solutions classiques apportées dans une industrie fixe, contrôles de substitution, de ventilation, de modification des procédés et contrôles administratifs, ne sont pas valables sur les chantiers et qu'il convient plutôt de contrôler les méthodes de travail. Les organismes de réglementation sont plus à même de juger du respect des normes s'il existe des règles détaillées et uniformes.

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[1] Labour Force Annual Averages 1975-1983. Statistics Canada Publication No. 71-529.

[2] Workers' Compensation Board of Ontario Firm Data – 1985

AIDS and the Workplace

AIDS (Acquired Immune Deficiency Syndrome) is caused by a virus which is present in the blood, semen and other body fluids of an infected person.

The virus is spread when infected blood or semen enters into another person's bloodstream. That happens through:

- sexual contact with an infected person
- sharing contaminated needles or syringes
- less commonly, through transfusion of infected blood or blood products.

Although very small traces of the virus have been found in tears and saliva, there have been no cases of anyone becoming infected from contact with these body fluids.

As the virus is not spread through nonsexual, everyday contact, there is little opportunity for infection in the workplace. If the AIDS virus were spread through everyday contact, there would be a dramatic increase in the number of cases and there would be more cases in women and children – and that's not happening.

Not everyone infected with the AIDS virus has AIDS or will develop AIDS. Some people are exposed to the virus, carry it in their bloodstreams and have no symptoms. Some may develop mild symptoms; others have more persistent symptoms known as PLS (persistent lymphadenopathy syndrome) or ARC (AIDS-related complex). A small number of the people who have been infected with the AIDS virus will develop the serious, fatal disease known as AIDS.

Can I Get AIDS From a Co-Worker Who Has AIDS?

There have been no cases of friends or co-workers being infected from nonsexual contact with persons with AIDS. There is no evidence that being in the same office, working on the same assembly line or using the same equipment as someone with AIDS – even for a long period of time – puts you at any risk of becoming infected with the AIDS virus.

Is There Any Risk in Using Cups, Telephones, Locker rooms or Other Facilities That Are Also Used by a Co-Worker Who Has AIDS or Who Has Been Infected With the AIDS Virus?

The AIDS virus has not been transmitted through air, water or food, or by touching the skin of a person with AIDS, or by touching any object handled, touched or breathed on by a person with AIDS. People can't get AIDS from public toilets, drinking fountains, telephones, public transportation or swimming pools.

Extensive studies of families of persons with AIDS have not found one case of the disease spread through sharing bathrooms, kitchenware or clothes.

Can I Get AIDS From Eating in a Restaurant Where Someone Handling the Food Has AIDS?

No cases of AIDS have been transmitted through food preparation or food handling. The AIDS virus is very fragile and survives for only a short time outside the human body. Even if the virus were present, it would be killed by the standard public health cleaning practices required of all restaurants or businesses handling food.

Personal Service Workers (such as Barbers and Manicurists) Have Fairly Close Contact With Customers. Are These Workers at Risk if the Customer Has AIDS or Is Infected With the AIDS Virus?

There has never been a case of a personal service worker becoming infected with the AIDS virus from nonsexual contact with a client or customer.

The risk of being exposed to the AIDS virus depends on the type of service performed. There is a potential risk *only* if the worker comes into contact with the client's blood *and* there is an opportunity for the virus to enter the worker's bloodstream.

Personal service workers such as hairdressers, barbers, beauticians, cosmetologists, manicurists and pedicurists may have close personal contact with clients, but they rarely come into contact with blood, and therefore have little risk of exposure.

Personal service workers who:

- pierce ears
- give tattoos
- use acupuncture

may come into contact with blood and, therefore, could be at some slight risk.

To protect against *any* infection, all personal service workers should follow good hygiene practices. They should:

- wash their hands thoroughly
- cover any cuts or sores on their hands
- clean their equipment according to recommended procedures
- use disposable equipment where appropriate
- clean anything that has been contaiminated with blood using rubbing alcohol or a bleach solution (1 part

household, chlorine bleach – such as Javex – to 9 parts water).

These simple precautions will protect against hepatitis B and other bloodborne infections – including AIDS.

If the Personal Service Workers Have AIDS or Are Infected With the AIDS Virus, Are Their Customers at Risk?

There has never been a case of someone becoming infected with the AIDS virus from nonsexual contact with a barber, hairdresser or other personal care worker. The good hygiene practices described for workers also protect customers.

Are Health Care Workers Who Are Caring for Persons With AIDS at Risk?

Health care workers and laboratory staff who handle body fluids such as blood, semen, feces and urine of AIDS patients run a slight risk of coming into contact with the AIDS virus. To protect themselves, they should follow the infection control practices and procedures recommended in their institutions so that the AIDS virus will not have the opportunity to enter their bloodstreams. Studies have shown that, even in cases where health care workers have accidentally stuck themselves with needles contaminated with blood infected with the AIDS virus, the chance of becoming infected with the AIDS virus is very small – well over 100 times less than with hepatitis B.

More detailed information for health care workers is available through the Ministry of Health.

Are Patients at Risk if the Health Care Worker Is Infected With the AIDS Virus?

Infection control procedures in hospitals or clinics that protect health care workers also protect patients. In most hospital situations, there is little opportunity for a patient to be exposed to the blood of a health care worker and, therefore, there is very little risk.

During invasive procedures, such as surgery or kidney dialysis, precautions are already in place to prevent bloodborne infections such as hepatitis B, and they would also protect against AIDS.

Are Ambulance Drivers, Police Officers, Firefighters and Other Emergency Workers at Risk of AIDS Virus Infection?

The AIDS virus is not spread by touching, carrying or holding a person who is infected. Nonsexual contact is not risky.

However, ambulance or other emergency personnel will likely come into contact with blood and other body fluids in emergency situations. *Even if these fluids contain the AIDS virus, the risk of infection is very low.* There have been no cases of anyone becoming infected with the

AIDS virus from providing emergency care for an infected person.

To protect against any infection, emergency workers should follow strict infection control practices in caring for emergency victims. They should:

- wash their hands thoroughly
- clean their equipment according to recommended procedures.

If they are likely to come into contact with blood or body fluids, they should:

- wear plastic, disposable gloves
- cover any cuts or sores on their hands
- clean any contaminated surfaces with a chlorine bleach solution.

These simple precautions will protect them from hepatitis B and other blood-borne infections – including AIDS.

Although very small quantities of the AIDS virus have been found in saliva, there have been no cases of AIDS virus infection transmitted through saliva. Emergency workers who *regularly* give mouth-to-mouth resuscitation or CPR to victims may protect themselves from a variety of diseases by using a specially designed mouthpiece. However, the risk of infection is so slight that no one should hesitate to give emergency mouth-to-mouth resuscitation without a mouthpiece.

What Should an Employer's Approach Be to an Employee Who Has AIDS?

As long as the employee is able to perform the essential duties of his or her job, the employer's approach should be the same as with any other employee.

At certain stages in the illness, the employee may be too ill to work. When this happens, or when the workplace becomes dangerous to the employee's health, the approach to the person with AIDS should be the same as with any other employee who has a serious illness. Whenever possible, attempts should be made to adjust work requirements to accommodate the person's health.

The employer should be sensitive to the fact that ongoing employment for someone who has a life-threatening illness is important, and may help to prolong the employee's life.

Can People Be Fired Because They Have AIDS or Are Infected With the AIDS Virus?

People who have AIDS or who are infected with the AIDS virus are not a health risk to co-workers so there is no medical reason to dismiss them.

The Ontario Human Rights Code prohibits discrimination in employment based on a disabling condition. If

a person were fired because he or she either:

- has AIDS,
- was infected with the AIDS virus, or
- was suspected of having AIDS,

that could be a violation of the employee's rights.

An employee who feels that his or her rights have been violated may file a complaint with the Ontario Human Rights Commission. In addition, the employee may be able to sue the employer for wrongful dismissal.

Can an Employee Refuse to Work with a Co-Worker Who Has AIDS or Who Has Been Infected With the AIDS Virus?

The Occupational Health and Safety Act allows workers to refuse to do a job that threatens their health. However, there has not been a single incident reported of someone becoming infected with the AIDS virus through nonsexual contact with a co-worker. Therefore, there is no medical reason to refuse to work with someone who is infected with the AIDS virus.

To prevent discrimination, a number of companies are developing internal policies on AIDS. Where policies exist, it may be a violation of the conditions of employment to refuse to work with someone who has AIDS or who is infected with the AIDS virus.

However, employers should be sensitive to co-workers' concerns and provide access to education to allay unreasonable fears.

Can a Health Care Worker Refuse to Provide Care for a Person With AIDS?

If a health care worker who is a member of a regulated profession refuses to care for someone who has AIDS, it may be a violation of the profession's standards of conduct. The circumstances should be brought to the attention of the governing body of that profession.

A number of hospitals and institutions have developed guidelines or policies on treating AIDS patients. In those cases, refusing to care for someone who has AIDS could be a violation of the institution's conditions of employment. A worker who refused to care for an AIDS patient could be disciplined or dismissed.

Anyone who has been refused care also has the right to file a complaint with the Ontario Human Rights Commission.

Can Someone Who Provides a Personal Service Refuse to Serve Someone Who Has AIDS or Who Is Infected With the AIDS Virus?

There have been no cases of anyone becoming infected with the AIDS virus from providing a personal service (e.g. hairdressers, barbers, etc.) to someone who has AIDS or who is infected with the AIDS virus.

Anyone who is refused a personal service can lodge a complaint with the Ontario Human Rights Commission.

Does an Employer Have the Right to Know if an Employee Has AIDS?

Since AIDS cannot be transmitted by everyday contact in the workplace, there is no need for employers, co-workers, neighbours or anyone who does not have intimate sexual contact with a person with AIDS to know. The person with AIDS has a legal right to privacy and confidentiality.

An employer can only request medical information from an employee that is relevant to his or her job. An employer can only confirm this information with a physician with the employee's expressed consent.

Should an Employer Request Blood Testing for Employees?

Available blood tests identify anti-bodies to the AIDS virus, which indicate that a person has been exposed to the virus. (See the Ministry of Health fact sheet: *Detecting AIDS*.)

Employers do not have the right to insist on mandatory blood testing.

Testing might be considered for health care workers who, through an injury in the workplace, have been exposed to infected blood or body fluids. In those cases, testing is for the benefit of the employee and should be voluntary – *not mandatory*.

In other work situations, there's no reason to test employees.

What Should Employers Do About AIDS?

Employers should set an example for their employees and refrain from discrimination. They should also take action to prevent discrimination among employees in the workplace.

Employers should help employees become informed. General information about AIDS is available from the Ministry of Health, from your local public health unit, from the AIDS Committee of Toronto and from other local AIDS groups. Employers should distribute information that will help employees understand the AIDS virus and how it is transmitted. More knowledge will mean less fear, less discrimination and greater productivity.

What Should Unions Do About AIDS?

Unions are a powerful force in communication and education and can help their members get accurate information about AIDS. They can also help prevent discrimination in the workplace. Union groups are forming committees to educate union leaders, staff and members about AIDS.

Employers, employees and union groups who would like to know more about AIDS are encouraged to take advan-

tage of the Ministry of Health AIDS Speakers Referral Service. Call the Ontario Public Education Panel on AIDS: in Toronto 965-2138, in the rest of Ontario 1-800-387-5586.

For more information, contact your doctor, your local STD (sexually-transmitted diseases) clinic, your public health unit (which is listed in the municipal section of the blue pages in your telephone directory), the AIDS Committee of Toronto or other AIDS organizations.

Although AIDS is a new disease, scientists have been following it closely since 1981. In that time, a great deal has been learned about the nature of the virus and how it is spread. As more information becomes available this fact sheet, and others in this series, will be updated.

The following fact sheets are available from the Health Information Centre, 9th Floor, Hepburn Block, Queen's Park, Toronto, Ontario M7A 1S2:

Information About AIDS
Information for Parents and Teachers
Detecting AIDS
Women and AIDS
AIDS and the Workplace

The content of this fact sheet was prepared by the Ontario Public Education Panel on AIDS (OPEPA) with advice from the Provincial Advisory Committee on AIDS, the Ontario Human Rights Commission, the Ontario Federation of Labour and the Inter-Ministerial Working Group on AIDS.

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Book Review

Clinical Occupational Medicine
Linda Rosenstock, M.D., M.P.H. and Mark R. Cullen, M.D.

Published by W.B. Saunders Company Canada Limited, One Goldthorne Avenue, Toronto, Ontario M8Z 5T9

Price $32.50 from the publisher.

The two principal authors of this book have, themselves, stated in the preface the manual's strong and weak points. This book was written to provide 'rapid access to concise, clinically orientated data for use in office or hospital practice', and a distinct advantage is that the book can fit easily in either a lab coat pocket or a briefcase. General background knowledge is assumed in internal medicine; no background is assumed for toxicology or industrial hygiene.

The format is similar to that of major occupational texts, i.e. 3 sections, namely,
1) fundamentals of occupational medicine,
2) approach to the patient by organ systems, and
3) hazards in the workplace organized by type of hazard.

In the authors' own words, the information may be 'incomplete, overly simplified or downright incorrect.' Certainly, the section on hazards is covered in greater detail in a standard text such as Rom's.[1] However, it is the second section that differentiates this manual from other standard texts. The clinical evaluation of each organ system is first discussed and then major disease groups of that system are classified, with known or suspected occupational causes given. Diagnosis, treatment and prognosis are discussed. The information is very brief in many cases and 'consultants and latest references should be used to supplement advice in this book.'

However, the manual fits the bill for rapid access to some basic general information that may be required either in the clinic or at the plant.

R. Nosal.

[1] Rom WN, (ed.) Environmental and Occupational Medicine. Boston: Little, Brown and Company, 1983.

Publications Available From the Government Book Store

Revised Regulations of Ontario, 1980 Regulation 692/80 Industrial Establishments	$2.00
Revised Regulations of Ontario, 1980 Regulation 691/80 Construction Projects	$2.00
Revised Regulations of Ontario, 1980 Regulation 694/80 Mines and Mining Plants	$2.00
Regulation respecting Lead – made under the Occupational Health and Safety Act Ontario Regulation 536/81	$1.00
Regulation respecting Mercury – made under the Occupational Health and Safety Act Ontario Regulation 141/82	$1.00
Regulation respecting Vinyl Chloride – made under the Occupational Health and Safety Act Ontario Regulation 516/82	$1.00
Regulation respecting Coke Oven Emissions – made under the Occupational Health and Safety Act Ontario Regulation 517/82	$1.00
Regulation respecting Asbestos – made under the Occupational Health and Safety Act Ontario Regulation 570/82	$1.00
Regulation respecting Asbestos on Construction Projects and in Buildings and Repair Operations – made under the Occupational Health and Safety Act Ontario Regulation 654/85	$1.00

Regulation respecting Isocyanates – made under the Occupational Health and Safety Act Ontario Regulation 455/83	$1.00
Regulation respecting Benzene – made under the Occupational Health and Safety Act Ontario Regulation 732/84	$1.00
Regulation respecting Acrylonitrile – made under the Occupational Health and Safety Act Ontario Regulation 733/84	$1.00
Regulation respecting Arsenic – made under the Occupational Health and Safety Act Ontario Regulation 176/86	$1.00
An Occupational Health Nurse's Guide to the Preparation of a Policy and Procedure Manual	$2.00
A Guide to the Occupational Health and Safety Act	$1.00
Regulation for X-ray Safety, Registration and Plan Review made under the Occupational Health and Safety Act Ontario Regulation 263/84	.60
X-ray Safety Code, Ontario Regulation 45/84	.20
Designated Substances in the Workplace: A General Guide to the Regulations	$2.00
Designated Substances in the Workplace: A Guide to the Lead Regulation	$1.00
Designated Substances in the Workplace: A Guide to the Benzene Regulation	$1.00
Designated Substances in the Workplace: A Guide to the Silica Regulation	$1.00

Designated Substances the Workplace: A Guide to the Mercury Regulation	$1.00
A Guide for Joint Health and Safety Committees and Representatives in the Workplace	$1.00

Coming Events

October 5 - 9, 1986	Twenty-ninth Biological Safety Conference, American Biological Safety Association, LEXINGTON, KENTUCKY. For further information, contact: Richard H. Kruse, MEDI, Inc., P.O. Box 11486, Lexington, Kentucky 40576 Tel: (606) 278-9815.
October 8 - 10, 1986	International Conference: Occupational and Environmental Significance of Chemical Carcinogens. BOLOGNA, ITALY. For further information, contact: M.A. Mehlman, North American Regional Secretariat, 7 Bouvant Drive, Princeton, New Jersey, 08540.
October 20 - 22, 1986	Frontier Health and Safety, Ottawa Congress Centre, OTTAWA, ONTARIO, CANADA. For further information, contact: Mr. K.A. Oakley, First National Health and Safety Symposium, P.O. Box 5218, St. John's, Newfoundland, Canada, A1C 5W1 (709) 726-7270.
November 9 - 12, 1986	Fourth Annual Meeting, Society for Risk Analysis, ANN ARBOUR, MICHIGAN. For further information, contact: Diane Taub, Executive Officer, SRA, c/o SASC, 1340 Old Chain Bridge Road, Suite 300, McLean, VA 22101.
November 19 - 21, 1986	Canadian Occupational Health Association and the University of Calgary – Conference 'Occupational Health Services in Canada Through the Year 2000'. CALGARY, ALBERTA, CANADA. For further information, contact: Madeleine Aldridge, Faculty of Continuing Education, The University of Calgary, 2500 University Drive, N.W., Calgary, Alberta, T2N 1N4. Telephone: (403) 220-7319.
November 30 - December 3, 1986	Wellness '86 Conference. TORONTO, ONTARIO, CANADA. For further information, please write: 700 Bay Street, 8th Floor, Toronto, Ontario M5G 1Z6, or call (416) 965-0283.

February 4 - 6, 1987	International Congress on Safety, Health and Environment, National Safety Council. SION, BOMBAY, INDIA - 400 022.
May 4 - 6, 1987	First Conference on Education and Training in Occupational Health, International Commission on Occupational Health. McMaster University, HAMILTON, ONTARIO, CANADA. For further information, contact: Mrs. P.M. Yake, Occupational Health Program, McMaster University, Health Sciences Centre, Room 3H50, 1200 Main Street West, Hamilton, Ontario, Canada, L8N 3Z5. Telephone: (416) 525-9140, Extention 2332.
May 24 - 30, 1987	ILO's 11th World Congress on the Prevention of Occupational Accidents and Diseases 'Co-operation Towards a Better Working Environment: The Future of Safety and Health at Work'. STOCKHOLM, SWEDEN. For further information, contact: Swedish Organizing Committee, Post Box 22236, S-104 22, Stockholm, Sweden.
September 27 - October 2, 1987	XXII International Congress on Occupational Health. SYDNEY, AUSTRALIA. For further information, contact: The Secretariat, XXII International Congress on Occupational Health, G.P.O. Box 2609. Sydney, N.S.W., Australia 2001.

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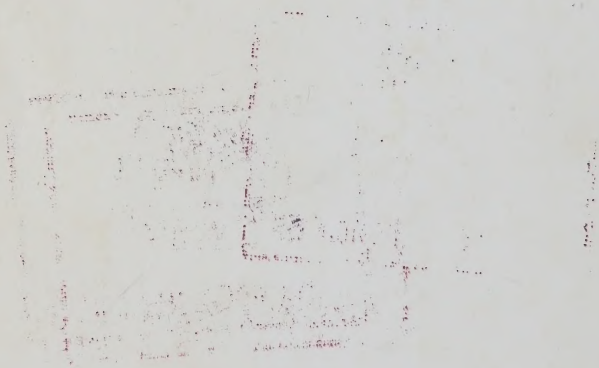
Ontario Ministry of Labour

Occupational Health and Safety Division

Occupational Health Branch

400 University Ave.
Toronto, Ontario
M7A 1T7

Telephone:
(416) 965-3610



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